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GEOTECHNICAL INVESTIGATION OF SOIL FOR BUILDING CONSTRUCTION

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KeyWords

Soil investigation report, sieve analysis, standard penetration test, moisture content, geotechnical investigation, bearing capacity , soil gradation, different soil tests.

ABSTRACT

Geotechnical investigation covers the determination of bearing capacity of soil, maximum dry density, soil starta, soil gradation, moisture content and atterberg's limits. In present study soil characterization was done for construction of 6 story building located in Mardan, KPK. The soil samples were characterized to calculate the design values for foundations. Design of foundation based on the results was later on implemented successfully indicating the adequacy of design and investigation method. The bearing capacity of soil was determined by using to methods first by using standard penetration test second by using Terzagi equation. Liquid limit and plastic limits were determined using 8mm threats and casagrande's apparatus respectively. In-situ moisture content was calculated by using oven dried method. Compressive strength of soil was determined using unconfined compressive test. Particle size gradation was done with sieve analysis and hydrometer analysis. Classification of the soil was done as per USCS and based upon the parameters and properties. Specific gravity of the soil was found using the Water Submersion Method. After finding all properties recommendations based on results, practices and data available were given for safe design of footing.

INTRODUCTION

Geotechnical investigation is of prime importance prior to construct any structure on ground as the load of structure is eventually transfer to soil beneath and it is necessary for soil to withstand this load during the life of structure. In field of construction geotechnical engineering is one of main pillars. Geotechnical engineering covers soil investigation, geotechnical designs and study of soil behavior under different conditions[13].

In geotechnical investigation different properties of soil are determined with the help of different tests and techniques. Determining soil behavior and its properties is quiet difficult as there isn't any method that can give exact behavior of soil all method which are used predict the behavior up to certain accuracy on the basis of practices and experiences. Soil characteristics like bearing capacity, maximum dry density, Moisture content, specific gravity, particle size distribution, settlement, consolidation and Atterberg's limits gives almost every necessary information of soil which is required for safe designs and other usages [5,6,8].

Geotechnical investigation and design only cost upto 3% of total project cost which is very small portion but it is very common practice that people try to save this amount and take a huge risk [1,4,6]. As if soil fails the complete structure will collapse resulting a total loss. By proper geotechnical investigation and designing there is a big opportunity of capital saving as the design will be base on real time data and will be economical as some time the client use heavy foundations, walls and other elements of the structure for safety purpose [10]. It also have much importance in highways and motorways as the most important thing to be consider in design of highways are the moisture base on which the drainage work of highways are decided. [9] The drainage of an area is dependent upon the soil type. Types of Foundation of structures are selected keeping in view the soil type and conditions. Inappropriate and Poor design of foundation may lead to structural failures, so a good design of foundation basing on site investigation and lab results is the first step in building construction[1].

METHODOLOGY

To prepare a geotechnical investigation report a project for the design of a multi-storey plaza in Mardan was selected.The job of conduct of Site Investigation was entrusted to the Material Testing Lab of Military College of Engineering. First of all the site for bore holes are selected to perform spt and collect samples for other test to be performed in lab.

Frame Work of Research Methodology

To achieve the stated objectives, first an SPT was performed on the borehole mentioned and field density test was performed in a test pit dug nearby. Samples, both disturbed and undisturbed, were obtained from the bore hole. For the extraction of undisturbed samples, Shelby tubes were used. Field testing and investigation was followed by lab testing and investigation.

Site Investigation And Laboratory Tests

Site Investigation is carried out to determine the properties of the underlying strata on which a structure is to be constructed. It is composed of a number of calculations based upon tests that are conducted on samples obtained from site [11]. Tests conducted in Site Investigation of the borehole included the following;

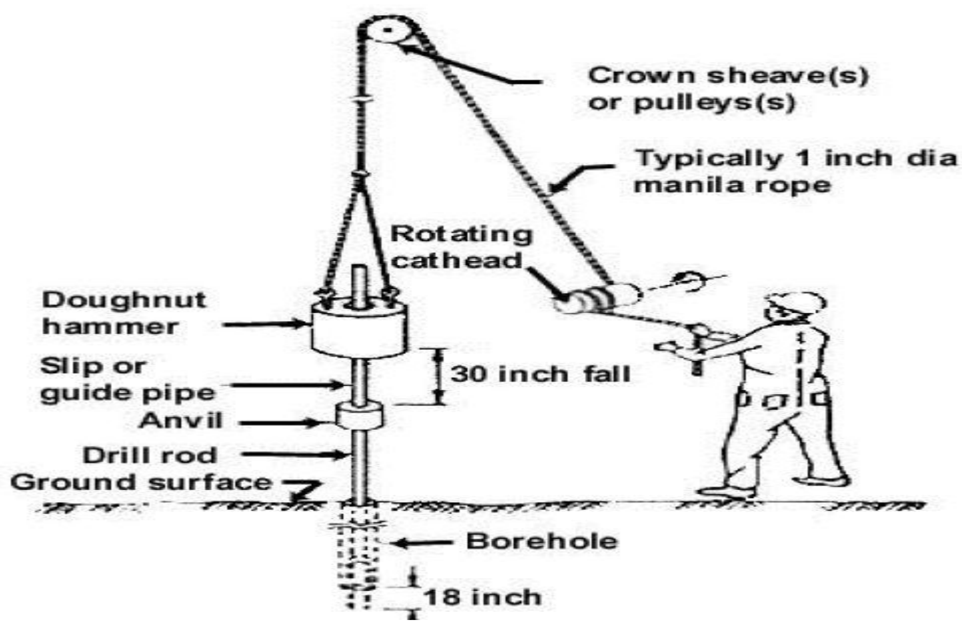
1. Standard Penetration Test (SPT)
2. Field Density and Moisture Content Tests
3. Specific Gravity Test
4. Particle Size Gradation
5. Atterberg’s Limits Tests

Unconfined Compression Tests

Standard Penetration Test and Field Density Tests are conducted in-situ while all other tests are conducted in a lab. A brief description of the tests involved in our study is given.

Standard Penetration Test

One of the most frequently used test to determine the strength of soil. It is based upon the principle that a stronger soil will require a larger force to penetrate [7,8,12].It involves the dropping of a standard load onto the soil and noting down the no. Of blows required to reach a standard depth. Empirical relationships are then used to determine the strength of soil by putting the values of no of blows. The number of blows was corrected for various parameters before being used in empirical formulae.SPT was performed at 7, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60ft depths. A hammer was lifted and dropped manually through ropes and with the help of a pulley hanged on to a tripod stand. Prior to the performance of the test all loose material was carefully removed. A split spoon sampler without a liner was used in all the tests to obtain Disturbed samples while Shelby tubes were used to obtain the Un-disturbed samples. Wherever groundwater was recorded in the boreholes, it was recorded in the respective bore-logs. At the time of investigation groundwater was encountered at 15ft depth below surface. Seasonal variations in the groundwater table can be expected fig given below [2,3].



(Fig showing SPT equipments)

Field Density Test

Field Density Tests are conducted in order to determine the density of soil. Density of a substance is the ratio of mass to volume. It is needed for the determination of phase relationships in other tests[9,10]. Performance of the test for the determination of field density is done on disturbed samples obtained from the tests pit on site by using core cutters. These core cutters have a standard and definite volume and weight. Field density of soil can thus be determined by dividing the mass of the soil by a know volume of soil, both these parameters can be determined from core cutters.

Specific Gravity Test

Specific Gravity is the ratio of the mass in air of a given volume of a material at a certain temperature to the mass in air of the same volume of gas-free water at a stated temperature (DOT-NY).Specific gravity of soil is required to determine various phase relationships in various tests in soil mechanics, although it is not a useful as a criterion for soil classification because of the minimal variability of specific gravity from soil to soil. For the determination of specific there are a number of methods, however in our investigation, we adopted the submersion technique. In this method mass of soil and water, that is displaced by it when put into a container of known volume and having

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a know amount of water in it, is determined as accurately as possible. Specific gravity corrections for temperature are also applied, for temperature = 20 degree centigrade, “k” was = 1.00

Particle Size Gradation Tests

Particulate materials are made up of a range and distribution of particle sizes. In most geotechnical applications, this distribution spans over varying sizes of particles. Grain size denotes the percentage of particles within a specified particle size range across all sizes represented for the sample. Table below shows the ranges of various soil types and their upper and lower boundaries. For the determination of particle size distribution in the soil samples obtained from the site were subjected to Particle Size Gradation Tests. Gradation tests also give us idea about the nature of the soil itself. For the classification of the sub-surface soil, selected soil sample was subjected to sieve analysis. Sample contained more than 30% material passing through No.200 sieve hence it was further subjected to hydrometer analysis. Results of both tests have been plotted in the form of gradation curve. For the purpose of classification of the subject soil, USCS (Unified Soil Classification System) was used. A brief description of Sieve analysis and Hydrometer analysis follows.

Sieve analysis

In this test, soil sample is subjected to pass various sized sieves and percent passing w.r.t to every size of the sieve is determined and plotted. The result of this analysis is a Grain Size Distribution Curve (GSD) which gives us particle size (on log scale) against % fines. From the GSD curve Coefficients of uniformity and Coefficient of distribution can be found by applying the respective formulae to ascertain the spread of grain sizes in the sample. This test can determine the grain size up to 75 micro meter. The following table is used to determine the nature of soil w.r.t particle size. The sample contained more than 30%fines by weight and therefore it was further subjected to Hydrometer Analysis.

	Sieve Size		Grain Size (mm)		
Soil Component	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Separation Technique
Boulders	12 in.	—	300	—	Manual Measurement
Cobbles	3 in.	12 in.	75	300	
Gravel					
Coarse	0.75 in.	3 in.	19	75	Mechanical Sieving
Fine	#4	0.75 in.	4.75	19	
Sand					
Coarse	#10	#4	2	4.75	
Medium	#40	#10	0.425	2	
Fine	#200	#40	0.075	0.425	
Fines	—	#200	—	0.075	Sedimentation

Table 8.1 USCS grain size boundaries.

Hydrometer Analysis

Hydrometer Analysis is employed to grade the sizes of the particles present in the sample that pass through #200 Sieve. It is based upon the principle that larger particles tend to settle down rapidly as compared to smaller particle when in the form of suspension. In this test a suspension of soil sample in prepared and then a standard hydrometer is used to determine the time for the settlement of various sized particles. Formulae are then applied to determine the diameter and % fines in suspension. Sodium hexameta phosphate is used as a dispersing agent in this test. Hydrometer Analysis is only applied when the %age by mass of soil passing through #200 Sieve is more than 30%. The result of this test is a GSD curve with diameter on x-axis (on log scale) and % passing of soil sample on y-axis.given in the figure below;

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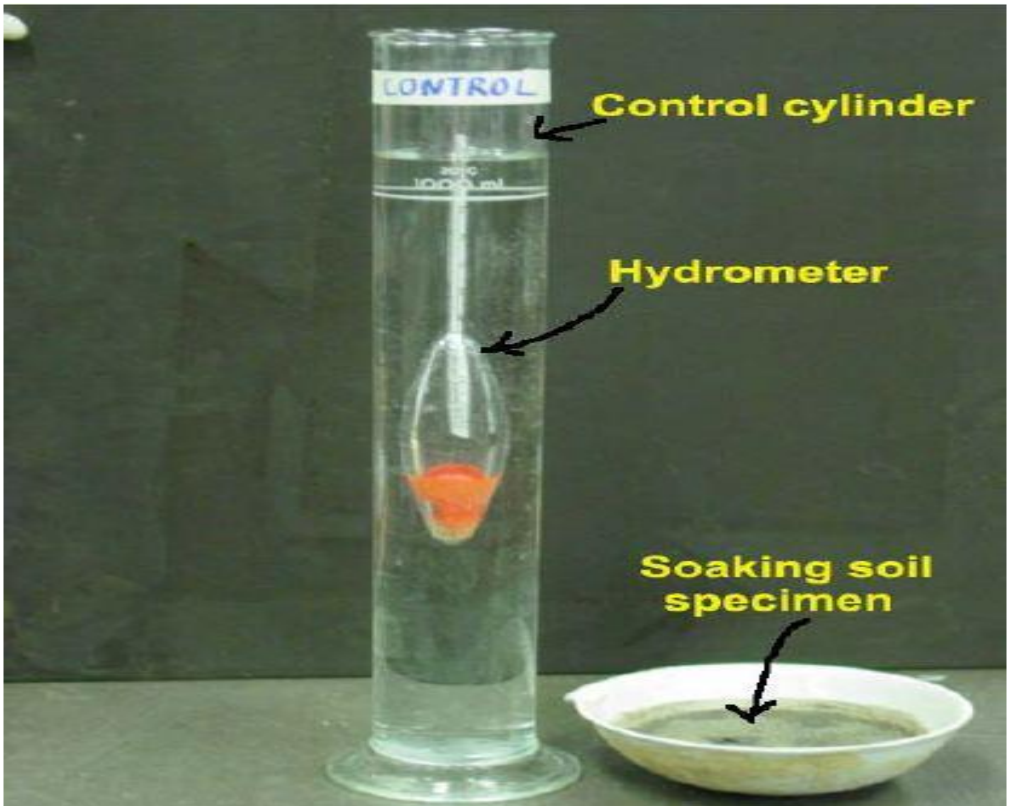

(Fig Showing Hydrometer Analysis)

Atterberg's Limits

For the evaluation of plasticity characteristics of the soil, liquid and plastic limit tests are performed on the soil sample. Liquid limit, Plastic limit and Plasticity Index of the soil are found. The Liquid limit is the moisture content at the division between the liquid and plastic state, whereas, the Plastic limit is the moisture content at the division between the plastic and semisolid state. The plasticity index is the numerical difference between the liquid limit and the plastic limit, it indicates the range of water content in which the soil remains in the plastic state. Liquid limit test was performed using Casagrande's apparatus. Sample was prepared at a known moisture content and placed in the apparatus. Groove was made in the sample and the number of blows needed to make the sample's grooves to meet were determined and plotted. The moisture content at 25 Nos. blows was the Liquid Limit. Similarly Plastic Limit tests was performed by making samples of known moisture content and then kneading it into threads on a glass pane. Plastic limit is the moisture content at which the soil rolls will start to crumble at 3mm dia.

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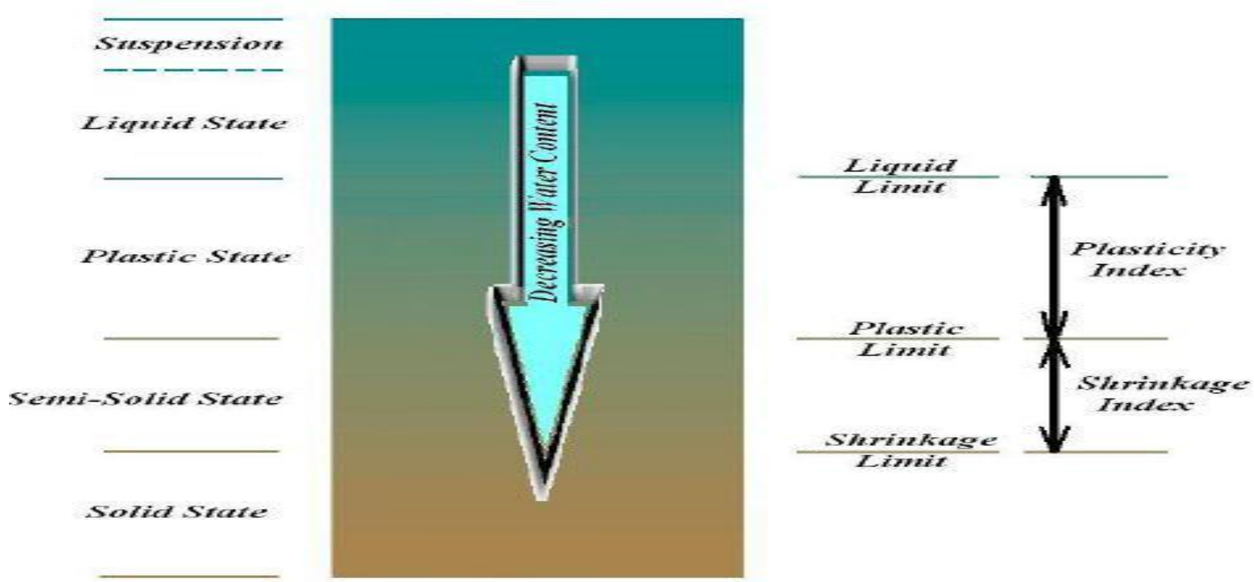


Atterberg Limits and Indices

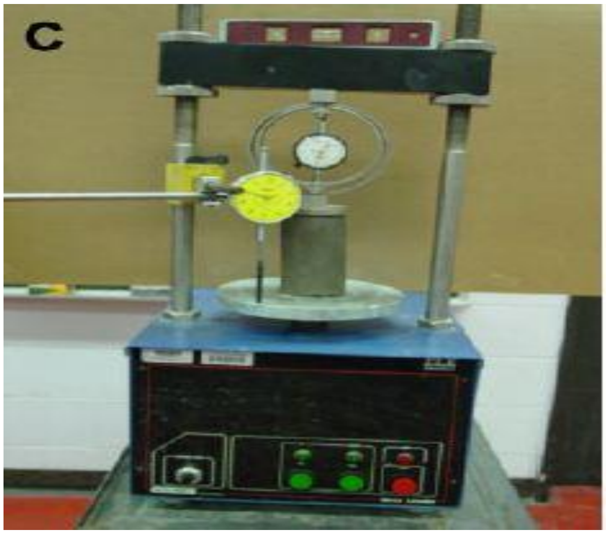
Figure 2 Diagrams Illustrating Liquid Limit Test

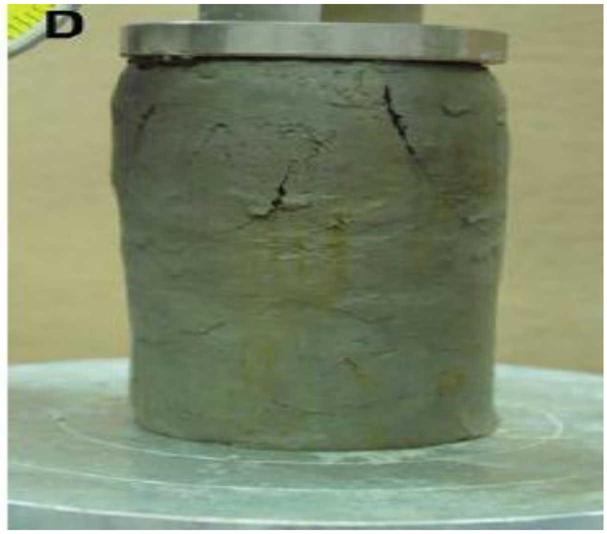
Moisture Content

Moisture content is the amount by weight of water present in a soil sample. It is an essential parameter and is also required to determine various other parameters of the soil sample. It is determined by measuring the change in weight of soil before and after oven drying.

Unconfined Compression

The primary purpose of this test is to determine the Unconfined Compressive Strength of the soil sample and which is then used to determine unconsolidated and un-drained shear strength of the soil sample. As per ASTM, unconfined compressive strength is defined as the compressive strength at which an unconfined cylindrical specimen of the soil will fail in a simple compressive test. In this test, max unconfined compressive stress is equal to the stress at failure or stress corresponding to 15% axial strain, whichever occurs first. An undisturbed soil sample is used to determine the strength of the soil. It is subjected to loading at a constant rate and loading and deformation is measured simultaneously. Area is corrected for various deformation values by applying corresponding formulae and stress corresponding to various strains is measured and plotted.The result is a stress-strain curve.Allowable bearing capacity of soil is found by applying requisite formulae on the results of this test. Shear strength of soil can also be determined from the unconfined strength of the soil and is equal to one half of the unconfined strength of the soil.





RESULTS

Field Density Test

FDT was carried out using the core-cutter method. Density of the soil was found by the ratio of mass of soil to volume of that mass. Volume of the core cutter was 0.0097cft. Mass of the soil was 1.14lbs, bulk density of the soil was found to be 117.5lbs/cft.

Moisture Content

Moisture content of a soil is the amount of water contained in the soil mass. Moisture content was found by Oven Dry Method. First the soil mass was weighted using scale and the weight was noted called M1, after that the same mass was kept in oven and dried for 24 hours and then weighted and the weight was noted called M2. After all necessary calculation the Moisture Content was found to be = 17.7%.

Standard Penetration Test

Standard Penetration Test was conducted in all the boreholes. The number of blows (N) = 6. Split Spoon Samplers w/o liner was deployed for the test; undisturbed samples of the soil were obtained using Shelby Tubes. A graphical bore-log was prepared, which is shown below, gives the information about N-values w.r.t depth, water-table, and soil type. Ground-water table was detected at 15ft depth. Bore log is shown in diagram

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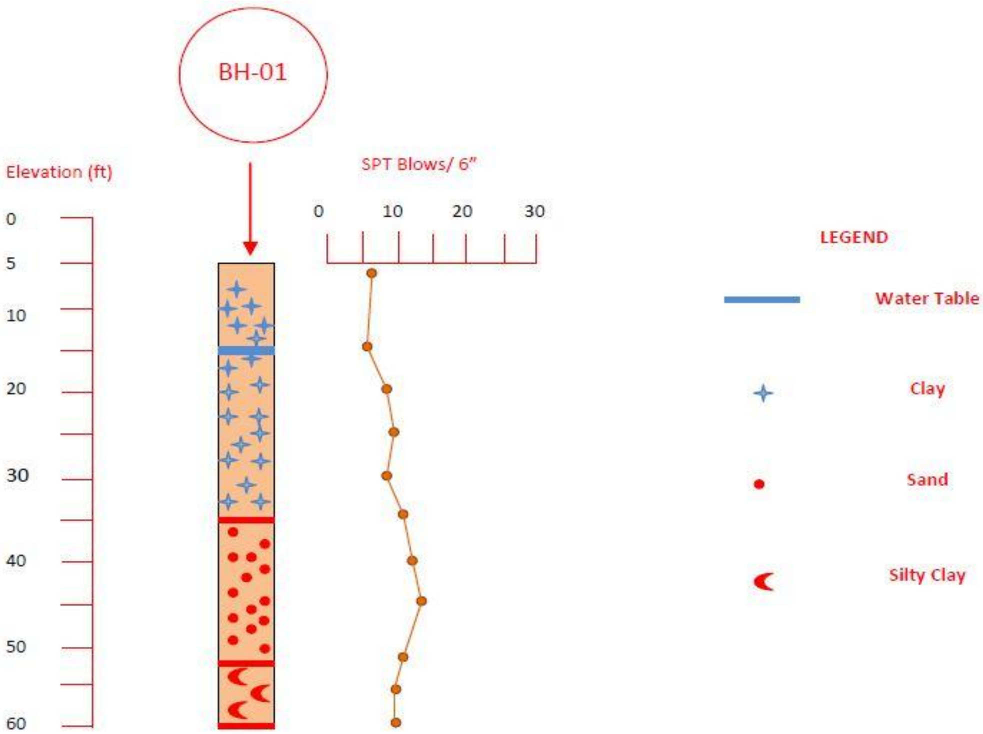

Bearing capacity results (By SPT) are given below. For the determination of bearing capacity of the soil, Terzaghi's equation for the strip footing was employed. Bearing capacity of 1.21 TSF was calculated.

SPT (Clay)

Detail	
γwet= Bulk Density lbs/cft	117.5
N= SPt No. of Blows	6
Df= Depth of foundation =ft	7
Po' = γwetxdf	822.50
CN=(2000/po)^0.5	1.56
Ń=NXCN x 0.8x 0.75	5.61
Qu= 0.25 x Ń =ksf	1.40
C= qu/2 =psf	1433.71
δn= ((Cx5.14)+γdf=kg/ cm2	8191.94
Qa=δn /3X2240=TSF	1.21

Unconfined Compression Test

Allowable Bearing Capacity was also found using the Unconfined Compression Test. Bearing Capacity as per UCC were lower than that of SPT. Therefore the allowable bearing capacity was taken to be 0.82 i.e. result obtained as per UCC test. Results of the UCC test are as following;

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Safe Bearing Capacity By UCC	
DR=	72.0
Def=	550.0
Dia of sample= cm	5.50
Ao= Πd2/4=cm2	23.76
Lo= mm	112.0
ΔL= defx0.01	5.50
Є= ΔL/L	0.05
Ac= Ao/1- Є =cm2	24.99
Qu=0.31xDR/Ac=kg/ cm2	0.89
C= Qu/2= lbs/ft2	921.39
δn= Cx5.14+γdf=kg/ cm2	5561.76
Qa= δn/(2240*3)= TSF	**0.82**

Particle Gradation Tests

Sieve Analysis and Hydrometer Analysis were carried out to determine the Particle size gradation curve and ultimately the type of soil encountered. For the classification of soil USCS was used. Results are attached.

Sieve Analysis Results

Sieve Analysis was carried out at depth below 35ft because the soil at top was clayey in nature and therefore Hydrometer Analysis was required. Results of the Sieve Analysis are as follows;

Hydrometer Analysis

As %age by weight of the soil passing through #200 sieve was more than 30% therefore Hydrometer Analysis was carried out. Results of the test have been attached. Composite Correction Factor=5 was used in the test. Test was conducted at room Temp. Specific Gravity was = 2.71.

Atterberg's Limits

Atterberg's Limits were found for the soil at top and at depth of 7 ft and below. Results of the tests are attached. Results were further used for the determination of the type of soil as per USCS which came out to be CL.

Specific Gravity

Specific gravity of the soil was found using the Water Submersion Method. Specific Gravity came out to be 2.71.

Soil Classification

Classification of the soil was done as per USCS and based upon the parameters and properties found above. Charts and tables below illustrate the process for a single set of data. Detailed results are given on Results Sheet.

In the borehole, as an example, at 35-60ft PL was 17.9%, LL was 24.6% and PI was 6.7, more than 50% of the soil was retained on #200 sieves. These values when used for the classification give us CL-ML from as per USCS Charts. Below is shown the detailed process;

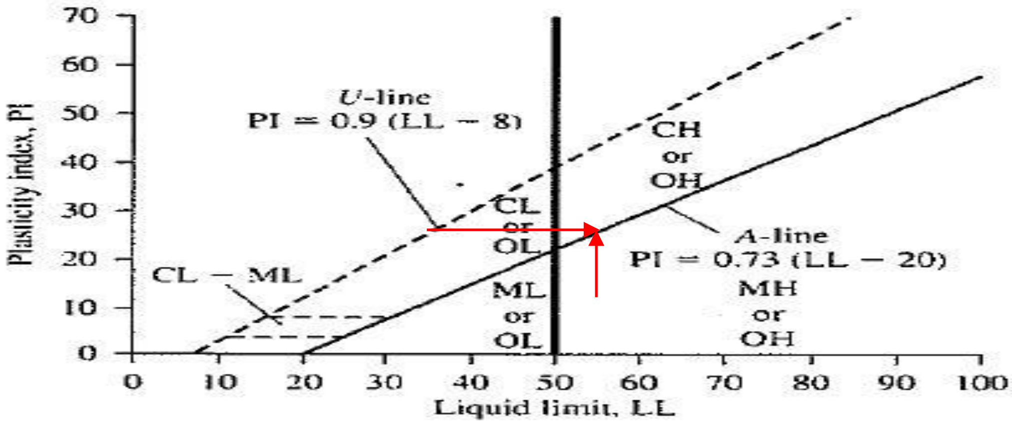

Figure 1.5 Plasticity chart

Table 1.6 Unified Soil Classification Chart (after ASTM, 2005)

Criteria for assigning group symbols and group names using laboratory tests[a]				Soil classification: Group symbol	Soil classification: Group name[b]
Coarse-grained soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[c]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[e]	GW	Well-graded gravel[f]
			$C_u < 4$ and/or $1 > C_c > 3$[e]	GP	Poorly graded gravel[f]
		Gravels with Fines More than 12% fines[c]	Fines classify as ML or MH	GM	Silty gravel[f,g,h]
			Fines classify as CL or CH	GC	Clayey gravel[f,g,h]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[d]	$C_u \geq 6$ and $1 \leq C_c \leq 3$[e]	SW	Well-graded sand[i]
			$C_u < 6$ and/or $1 > C_c > 3$[e]	SP	Poorly graded sand[i]
		Sand with Fines More than 12% fines[d]	Fines classify as ML or MH	SM	Silty sand[g,h,i]
			Fines classify as CL or CH	SC	Clayey sand[g,h,i]
Fine-grained soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[j]	CL	Lean clay[k,l,m]
			PI < 4 or plots below "A" line[j]	ML	Silt[k,l,m]
		Organic	(Liquid limit—oven dried) / (Liquid limit—not dried) < 0.75	OL	Organic clay[k,l,m,n]; Organic silt[k,l,m,o]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay[k,l,m]
			PI plots below "A" line	MH	Elastic silt[k,l,m]
		Organic	(Liquid limit—oven dried) / (Liquid limit—not dried) < 0.75	OH	Organic clay[k,l,m,p]; Organic silt[k,l,m,q]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat

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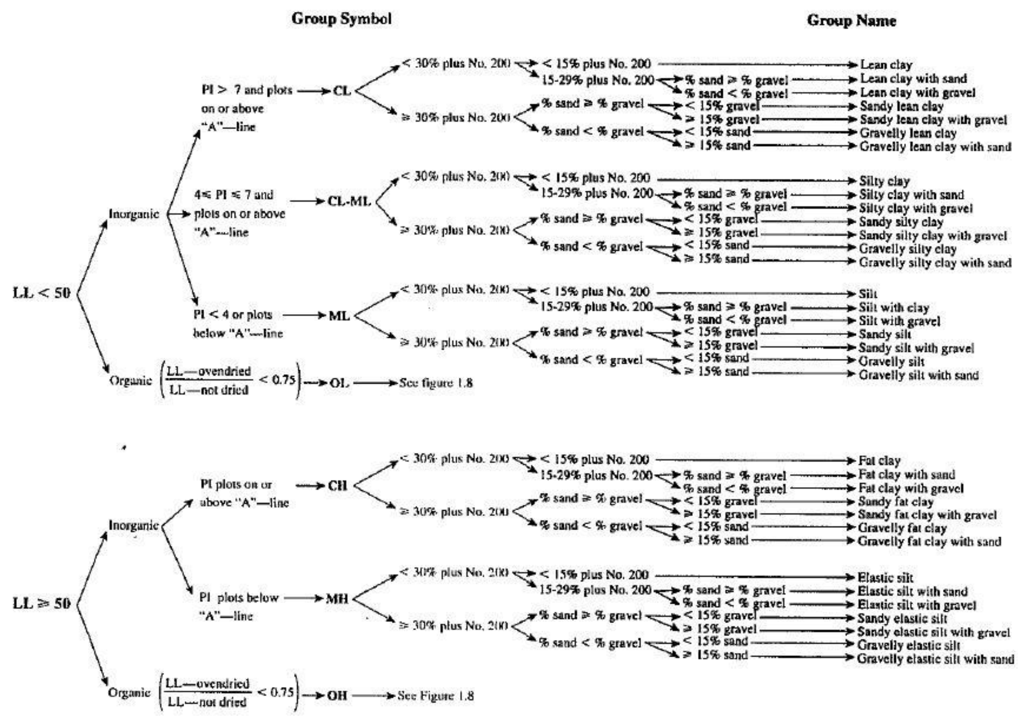

Figure 1.7 Flowchart for classifying fine-grained soil (50% or more passes No. 200 Sieve) (After ASTM, 2005)

CONCLUSION

1. During the investigations the subsurface was explored up to a maximum depth of 60ft below the surface of ground. Location of borehole has been shown in the attached site plan for reference. Various soil layers encountered at the site below the existing surface have been described in detail in the spread sheet and bore-log attached. The soil was, generally, clay in nature.
2. Ground water table was encountered in the borehole at a depth of 15ft. It is therefore recommended that adequate surface drainage should be provided along with waterproofing to avoid damage by water. In case foundation is to be constructed and placed below water table then sufficient dewatering must be carried out during the construction of the foundation and the water level be maintained at 2ft below foundation level.
3. Terzaghi's Equation for bearing capacity has been used for computation of allowable bearing capacities. An FOS of 3 was used in calculating allowable bearing capacity. Additionally, Unconfined Compression Tests was conducted on undisturbed samples obtained from 7ft depth. Test results suggest that the soil in general is low plastic "clay". The Atterberg's Limit tests performed on the soil samples resulted in plasticity index from 9-12% which also suggest that the material is of low plasticity (CL). The specific gravity tests performed on soil samples resulted in to a specific gravity of 2.71. Bearing capacity of the soil was found to be 0.82 as per UCC and 1.21 as per SPT at 7 ft depth.

Acknowledgment

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